ABSTRACT

Nowadays, many companies are struggling in producing cleaner energy in order to overcome the oil depletion problem. Of late, the use of hydrogen has become a hot topic discussed among inventers as it has the ability to assist as well as posses the potential in becoming a new form of alternative source for transportation. In this thesis, a conceptual study of a hydrogen powered bicycle by using fuel cell technology is studied. In this study, a small hydrogen generator with nine plates of stainless steel was fabricated. The hydrogen generator is capable of producing desirable quantities of hydrogen. The mass flow rate of the hydrogen was computed based on the current supplied. A rechargeable battery was chosen due to long life span and low maintenance. Apart from that, due to its desirable light weight properties, the hydrogen consumption of the bicycle is reduced. A brushless electric motor providing 200 Watt power to drive the bicycle was fitted. The maximum weight that the bicyle is able to withstand is around 60 kg, while the maximum speed attained is 25 km/hr under such weight considered.

ABSTRAK

Dalam marcapada ini, banyak syarikat-syarikat besar bertungkus-lumus menghasilkan tenaga mesra alam demi mengatasi masalah sumber bahan mentah yang semakin berkurangan. Akhir-akhir ini, penggunaan hidrogen telah menjadi satu topik hangat dibincangkan di kalangan penyelidik kerana ia mempunyai keupayaan untuk membantu serta memiliki potensi untuk menjadi satu bentuk baru sumber alternatif bagi pengangkutan. Dalam tesis ini, satu kajian konsep basikal berkuasa hidrogen dengan menggunakan teknologi sel bahan api dikaji. Dalam kajian ini, penjana hidrogen kecil dengan sembilan plat keluli tahan karat telah dihasilkan. Penjana hidrogen mampu menghasilkan kuantiti yang diingini hidrogen. Kadar aliran jisim hidrogen itu dikira berdasarkan arus yang dibekalkan. Bateri boleh dicas semula telah dipilih kerana jangka hayat yang panjang dan penyelenggaraan yang rendah. Selain daripada itu, kerana sifat bateri yang lebih ringan, penggunaan hidrogen untuk menggerakkan basikal dikurangkan. Sebuah motor elektrik membekalkan kuasa sebanyak 200 Watt untuk menggerakkan basikal telah dipasang. Berat maksimum yang yang mampu ditampung adalah sekitar 60 kg, manakala kelajuan maksimum yang mampu dicapai adalah 25 km/jam.

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LIST OF SYMBOLS

C_d	Drag coefficient
v_0	Initial velocity
v	Velocity
t	Time taken
f_μ	Friction force
f_D	Drag force
ρ	Density
μ	Viscosity

CHAPTER 1

INTRODUCTION

1.1 FUEL CELL

The first basic fuel cell was built and demonstrated by Sir William Robert Grove. He was using four large cells, each containing hydrogen and oxygen, to produce electric power which was then used to split the water in the smaller upper cell. Commercial potential first demonstrated by NASA in the 1960's with the use of fuel cells on the Gemini and Apollo space flights. However, these fuel cells were very expensive fuel cells. Fuel cell research and development has been actively taking place since the 1970's, resulting in many commercial applications ranging from low cost portable systems for cell phones and laptops to large power systems for buildings [1].

Quite simply, a fuel cell is a device that converts chemical energy into electrical energy, water, and heat through electrochemical reactions. Fuel and air react when they come into contact through a porous membrane (electrolyte) which separates them. This reaction results in a transfer of electrons and ions across the electrolyte from the anode to the cathode. If an external load is attached to this arrangement a complete circuit is formed arrangement, a complete circuit is formed and a voltage is generated from the flow of electrical current.

The voltage generated by a single cell is typically rather small which is less the one volt, so many cells are connected in series to create a useful voltage because the intermediate steps of producing heat and mechanical work typical of most conventional power generation methods are avoided, fuel cells are not limited by thermodynamic limitations of heat engines such as the Carnot efficiency. In addition, because combustion is avoided, fuel cells produce power with minimal pollutant. However, unlike batteries the reductant and oxidant in fuel cells must be continuously replenished to allow continuous operation.

Most fuel cell power systems comprise a number of components:

i. Unit cells, in which the electrochemical reactions take place
ii. Stacks, in which individual cells are modularly combined by electrically connecting the cells to form units with the desired output capacity
iii. Balance of plant which comprises components that provide feed stream conditioning (including a fuel processor if needed), thermal management, and electric power conditioning among other ancillary and interface functions

Hydrogen powered bicycle that using fuel cell as the main power to the bicycle are offering a cheap and efficient mode of transportation. They are becoming increasingly popular in many countries such as Japan. These modes of transportation are suitable for nearby distance where people do not feel exhausted while going to their destination. Some may be carried they heavy stuff and using the bicycle powered hydrogen, they do not have to cycle to the nearby destination where they just start the fuel cell and off they go. Power assisted bicycle are usually powered by either lead-acid or nickel-cadmium, with motor power ratings between 200 and 400 W, depending on the make and type. Recently, the fuel cell has been considered as a means to provide direct power to power assisted bicycle, or more likely to charge the battery which, in turn, drives the motor.

Wherever possible, the components chosen for the fuel-cell system are commercially available [2]. Also in this past 15 years, some country like the United Arab Emirates have been using have spent nearly $\$20X10^9$ on roads, highways, bridges and tunnels [3]. The objective of building these was to ease vehicular flow and to shorten traveling time between the cities. When the highway was developed on the map of emirates the demand for internal combustion engine was booming. Higher demand for better livelihoods and innovative technologies and the lower cost of fossil fuels a comparison with other nations. This increase in the utilization of vehicles along with industrial plants has led to serious environmental consequences, such that energy related carbon emissions in the UAE in 1998 was estimated to be 31.3 million metric tons of carbon, which was 11.5 metric tons of carbon per capita as compared to the USA, which was 5.5 metric tons of carbon per capita [4].

One of the key measures to reduce environmental pollution caused by automobiles is to introduce vehicles running by fuel cells, especially the proton-exchange membrane fuel-cell (PEMFC) vehicles. These types of vehicles are powered by a clean fuel namely hydrogen energy. Besides proton exchange membrane fuel cell vehicles being environmentally clean, they operate at low temperatures and achieve quick responses, they are at least 3 0% more efficient than IC vehicles since they are not limited by the Carnot Cycle [6]. In addition, they have less hardware parts and do not generate noise like internal combustion vehicles.

Many automotive manufacturers and power industry research organizations have shown interest in this new technology in the past few years, due to its attractive features. Major car companies in the world are now involved in the development and commercialization of hydrogen-fueled motor vehicles. Most of these companies such as BMW, Daimler–Chrysler, Ford, GM, Toyota, Nissan and Honda are preparing to commercialize hydrogen-fueled cars in 2004 [7]. In the past few years, some policies and schemes were presented concerning reduction of greenhouse gas emissions caused mainly by automobiles. Some studies were conducted on the utilization of proton exchange membrane fuel-cells in hybrid electric vehicles such as works of Krepec and Hong [8], and Jorgensen [9], while others will conduct a general study on the projected utilization of electric vehicles in the future [10].

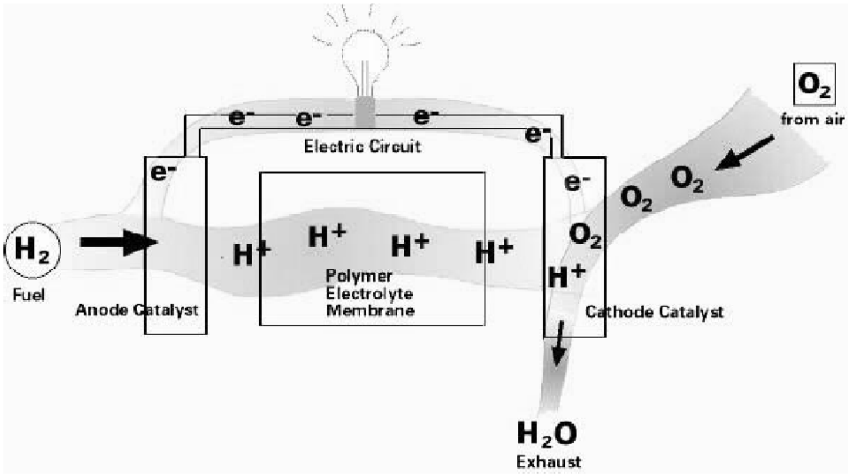

Figure 1.1: Basic concept of fuel cell

Source: Sharon Thomas. 2001

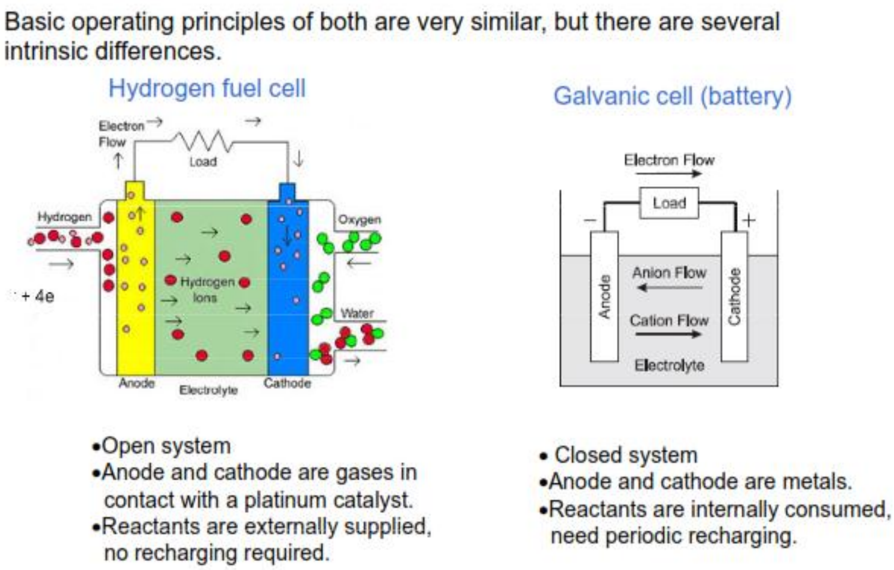

Figure1. 2: Fuel cell Vs Battery

Source: Sharon Thomas. 2001

1.2 PROJECT BACKGROUND

In this project, design and development of fuel cell for bicycle will be conducted. The details phases of the new fuel cell development, from concept design consideration to hardware selection, fabrication and finally the testing process will be studied.

Next the design concept or sketching the prototype of a fuel cell for bicycle will be evaluated in order to select the best design and drawn using Solidwork or AutoCAD software's prior to the final design being fabricated but before that the system for fuel cell need to be sketched in order to see the whole system thoroughly. This can help me continue on planning the next step. Hydrogen generator can be man-made or can do pre-order anyway around Kuantan.

This process will follow by the fabrication process in order to develop the design. Fabrication process involves all basic mechanical processes such as grinding, drilling, cutting and etc. Once the fabrication process finished, the hydrogen generator, fuel cell and the motor will be attached to the bicycle. The test run will be conducted if all the component valid and functional as well

1.3 PROBLEM STATEMENTS

This study is about the design and develops the fuel cell and hydrogen generator for bicycle. The design of the fuel cell needed to be finalized as it will be used in the process. The schematic diagram of the fuel cell still and how actually the system working is still unknown. Hydrogen generator is also a problem where it is should be fitted to the bicycle and working fine. The real dimension also still not available so how large the hydrogen generator are will be determined later.

The whole system of how the hydrogen will be produced and where it is starting and where it will ended are unexplainable. This project will focus on the fuel cell where the selection of components is the crucial part in this study. A few design needs to be done to see how the component fit on the bicycle. Lastly the material for the whole project from the hydrogen generator, fuel cell and motor are needed to be confirmed so that list of material can be done.

1.4 RESEARCH OBJECTIVES

The main objectives of the study are:

a) To study on the compact hydrogen powered bicycle.
b) To design a control system for hydrogen powered bicycle.

1.5 SCOPES OF THE RESEARCH

a) Research about fuel cell
b) Design a fuel cell so it can be fitted to the bicycle

CHAPTER 2

LITERATURE REVIEW

2.1 THE POLYMER ELECTROLYTE MEMBRANE (FUEL CELL)

An ordinary electrolyte is a substance that dissociates into positively charged and negatively charged ions in the presence of water, thereby making the water solution electrically conducting. The electrolyte in a polymer electrolyte membrane fuel cell is a type of plastic,a polymer, and is usually referred to as a membrane. The appearance of the electrolyte varies depending upon the manufacturer. In an operating fuel cell, the membrane is well humidified so that the electrolyte looks like a moist piece of thick plastic wrap. Only the positive ions contained within the membrane are mobile and are free to carry positive charge through the membrane.

In polymer electrolyte membrane fuel cells these positive ions are hydrogen ions, or protons, hence the term proton exchange membrane. Movement of the hydrogen ions through the membrane, in one direction only,from anode to cathode, is essential to fuel cell operation. Without this movement of ionic charge within the fuel cell,the circuit defined by cell, wires, and load remains open,and no current would flow back bone, polymer electrolyte membranes are relatively strong, stable substances. Although thin, a polymer electrolyte membrane is an effective gas separator. It can keep the hydrogen fuel separate from the oxidant air, a feature essential to the efficient operation of a fuel cell [12]. Although ionic conductors, polymer electrolyte membranes do not conduct electrons.

The organic nature of the polymer electrolyte membrane structure makes them electronic insulators, another feature essential to fuel cell operation. As electrons cannot move through the membrane, the electrons produced a tone side of the cell must travel, through an external wire, to the other side of the cell to complete the circuit.It is in their route through the circuitry external to the fuel cell that the electrons provide electrical power to run a car or a power plant

2.2 THE ELECTRODES

All electrochemical reactions consist of two separate reactions, an oxidation half-reaction occurring at the anode and a reduction half-reaction occurring at the cathode. The anode and the cathode are separated from each other by the electrolyte, the membrane. In the oxidation half-reaction, gaseous hydrogen produces hydrogen ions, which travel through the ionically conducting membrane to the cathode, and electrons which travel through an external circuit to the cathode. In the reduction half-reaction, oxygen, supplied from air flowing past the cathode, combines with these hydrogen ions and electrons to form water and excess heat.

These two half-reactions would normally occur very slowly at lower operating temperatures, typically 80^{o}C, of the polymer electrolyte membrane fuel cell. Thus, catalysts are used on both the anode and cathode to increase the rates of each half-reaction. The catalyst that works the best on each electrode is platinum, a very expensive material [13]. The final products of the overall cell reaction are electric power, water, and excess heat. Cooling is required, in fact to maintain the temperature of a fuel cell stack at about 60 degree celcius. At this temperature, the product water produced at the cathode is both liquid and vapor. This product water is carried out of the fuel cell by the air flow

2.3 BIPOLAR PLATES

2.3.1 Metallic Bipolar Plate Materials

Some applications of fuel cell were of high cost. Some example is fuel cell submarines. Here, expensive corrosion-resistant metals were used as bipolar plate materials. Corrosion may occur at the anode as it often does on the cathode side. Air and positive potentials at the cathode usually lead to the growth of metal oxide layers, causing an increase in the electrical resistance. Therefore, substrates and coatings have been investigated to get the optimal material combination. The reducing environment at the anode of the fuel cell leads to a reduction of the oxide protective layer of metallic materials, hydride formation, and dissolution of the metal in product water or humid hydrogen feed gas as a consequence. Bipolar plate steel is made of stainless steel, titanium, aluminum, and several metal alloys [14]. Two classes of coatings can be classified into two that is carbon based and metal-based. Carbon-based coatings mainly comprise conducting polymers such as the polyaniline, polypyrrole, and diamond-like carbon [14].

Metal-based coatings include noble metals, metal nitrides, and early transition metal elements such as molybdenum, vanadium, and niobium that forms a thin oxide layer that covers the metal layer against corrosion [14]. Bipolar plates generally made of stainless steel, titanium, aluminum and several metal alloys. For coating some material may have several consequences such as the titanium where it is quite expensive and aluminum where it requires perfect coating otherwise pitting corrosion will occur. The production process of bipolar plates out of steel is a forming method like stamping or hydroforming.

2.3.2 Graphite Bipolar Plate Materials

Graphite was already known in the industry for its application acid fuel cell to be a suitable material. Pure graphite-based bipolar plates offer the advantages of chemical resistance and good thermal and electrical conductivity combined with a lower density than metal plates. However, machining the flow fields into pure graphite plates is a complicated and time-consuming step that leads to high prices. Additional, the graphite-based are brittle and porous where they need to be coated to be impermeable to the fuel and oxygen.

Hence, it has become the not practicable candidates as low-cost fuel cell components Graphite composite materials with polymer binders are more suited to achieve the desired properties and to improve manufacturing technologies for bipolar plates including the flow fields and cooling channels [14]. These composite materials are made of commercially available polymers as binders and high loading of conductive carbon compounds that increase the conductivity. The polymers are either thermoplastics such as polyvinylidene fluoride, polyethylene, polypropylene, liquid crystal polymers, and polyphenylene sulfide, or thermosets, such as vinyl ester, phenolic resins, and epoxy resins [14].

2.3.3 Flow Field Design

There are four different types of flow fields that have been investigated in the past: pin-type flow field, parallel channels flow field, serpentine flow field, and interdigitated flow field.The pin-type flow field consists of an array of columnar pins arranged in a regular pattern

The shape of the individual pins is generally cubical or circular. As the reactant gases flow through a network of series and parallel flow paths, only low pressure drops occur. Preferred flow path according to the principle of least resistance can, however, lead to inhomogeneous reactant distribution and locally insufficient product water removal [15].

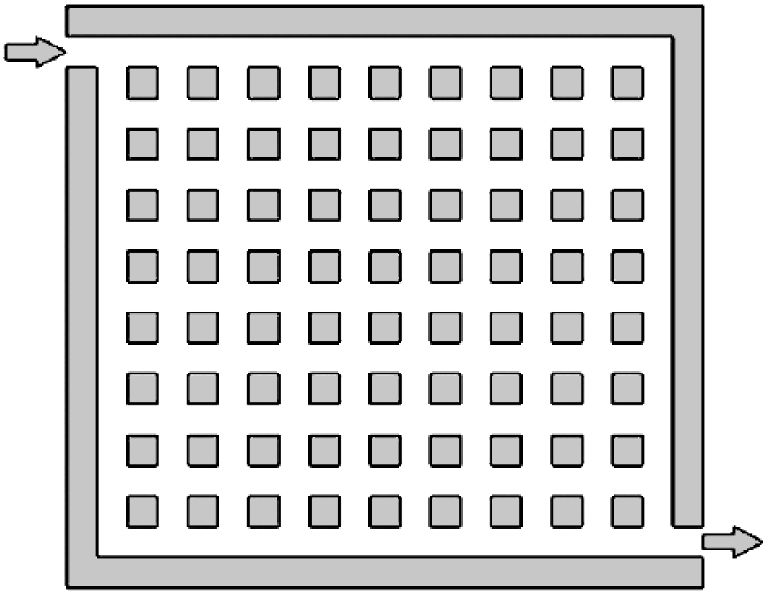

Figure 2.1: Schematic drawing of a pin-type flow field.

Source: A Heinzel 2009

The parallel channel type of flow field is typically used when no accumulation of water droplets is expected. If droplets form, they may block one or more of the parallel channels, while the remaining gas stream flows through the least blocked channels. This is possible due to the low pressure drop of multiple parallel channels. If fuel and oxidant are supplied in excess of what is stoichiometrically used by the electrochemical reaction, parallel flow fields are applicable.

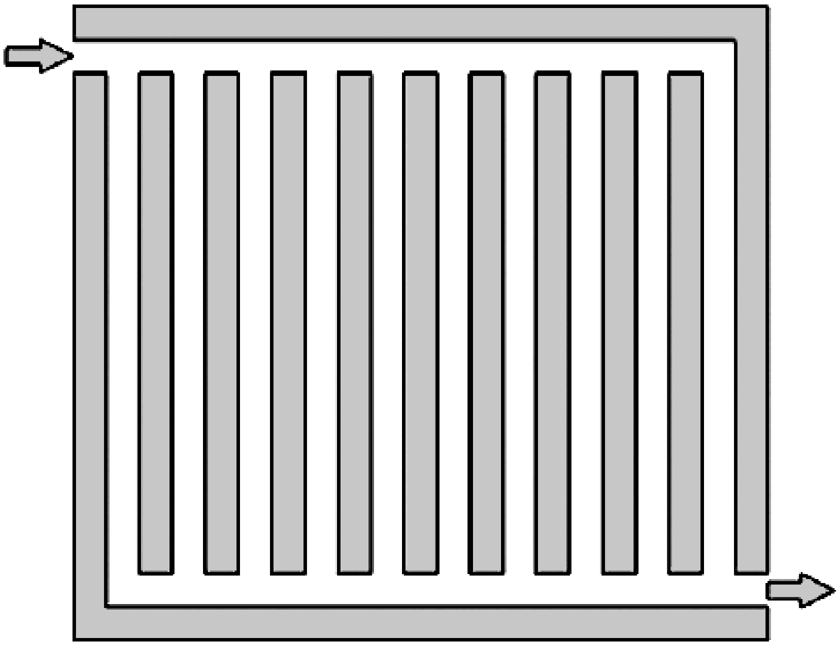

Figure 2.2: Schematic drawing of a parallel channel flow field.

Source: A Heinzel 2009

The danger of droplet accumulation can also be reduced to a large extent by recirculating part of the gases and condensing excess product water outside of the fuel cell stack. The same argument holds for pin-type flow fields. As the pressure drop in the multiple parallel channels of each cell is small, attention has to be paid to the pressure drop in the gas distribution manifold of the stack. If it is larger than the single-cell pressure drop, this will lead to uneven reactant gas supply to the individual cells of a stack, favoring the cells that are close to the multiple inlet [15].

The interdigitated flow field consists of multiple dead ended flow channels. Its main characteristic is a forced gas flow through the adjacent diffusion layer, which means active transport of reactants in close vicinity to the electrode. If products are accumulating in the gas diffusion layer, the forced flow represents a significant advantage but the pressure drop in this flow field is dependent on the properties mainly porosity and hydrophobicity of the gas diffusion layer. As these properties are known to be subject to aging processes, this type of flow field is not very common.

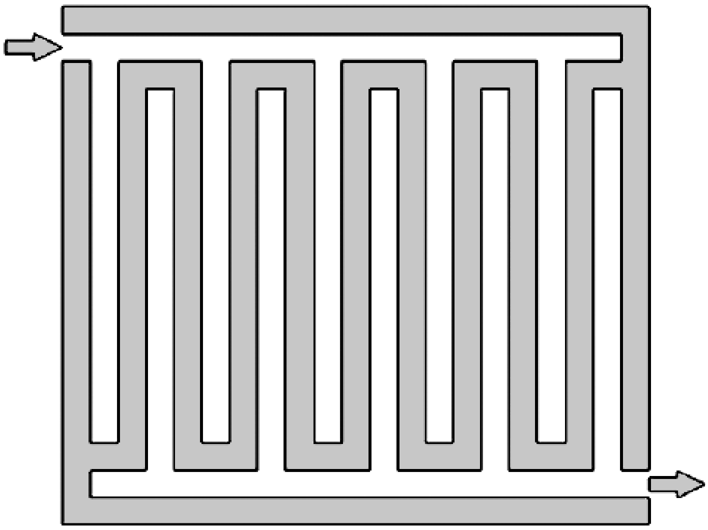

Figure 2.3: Schematic drawing of an interdigitated flow field.

Source:A Heinzel 2009

Most fuel cell developers use any type of serpentine flow field, a compromise between pressure drop requirements and water removal aspects. In a single serpentine, oxygen depletes with the length of the path, leading to a decrease in current density along the channel. Real flow fields, therefore, include multiple serpentine channels and, in addition, inlet and outlet parts of the channels can be placed close together [15]. Leading to sites of high hydrogen concentration and low humidity (hydrogen inlet) and low hydrogen concentration and high humidity (hydrogen outlet) being close together. Thus, a certain equalization of conditions and performance is possible.

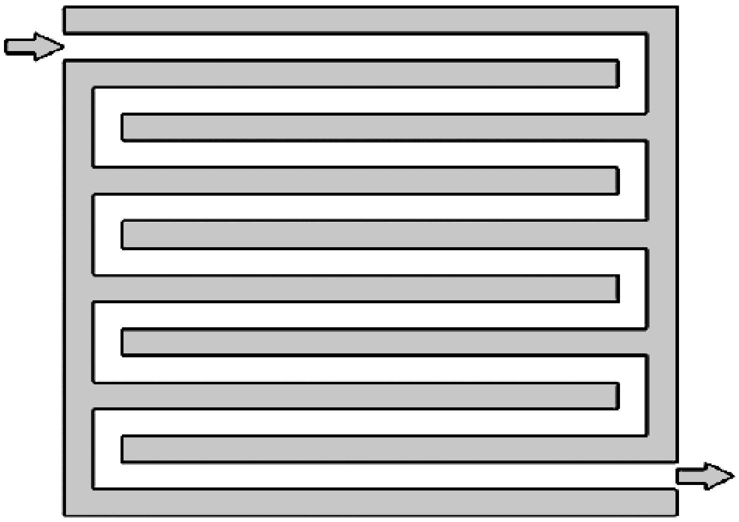

Figure 2.4: Schematic drawing of a single serpentine flow field.

Source: A Heinzel 2009

CHAPTER 3

METHODOLOGY

3.1 PLANNING

Several methods are selected to get the project done smoothly. The project must be done according to the objective and run effectively. The Gantt chart and flow chart are must have item in methodology in achieving objectives. The fuel cell needed to be sketched and the dimension are need to be precise so that right dimension can be selected for the bicycle and the design must be suitable for the bicycle so that it is not that over-estimate.

For the hydrogen generator, since it seems that the fabrication are achievable. The hydrogen generator should be a small one and flexible so that it can be put anywhere on any bicycle parts and it still can produce hydrogen efficiently.

Lastly the bipolar plate, with ump technology has the plates can be fabricated with forming machine according to the original design. This design would be different from the usual one since different design produces different results.

3.2 GANTT CHART

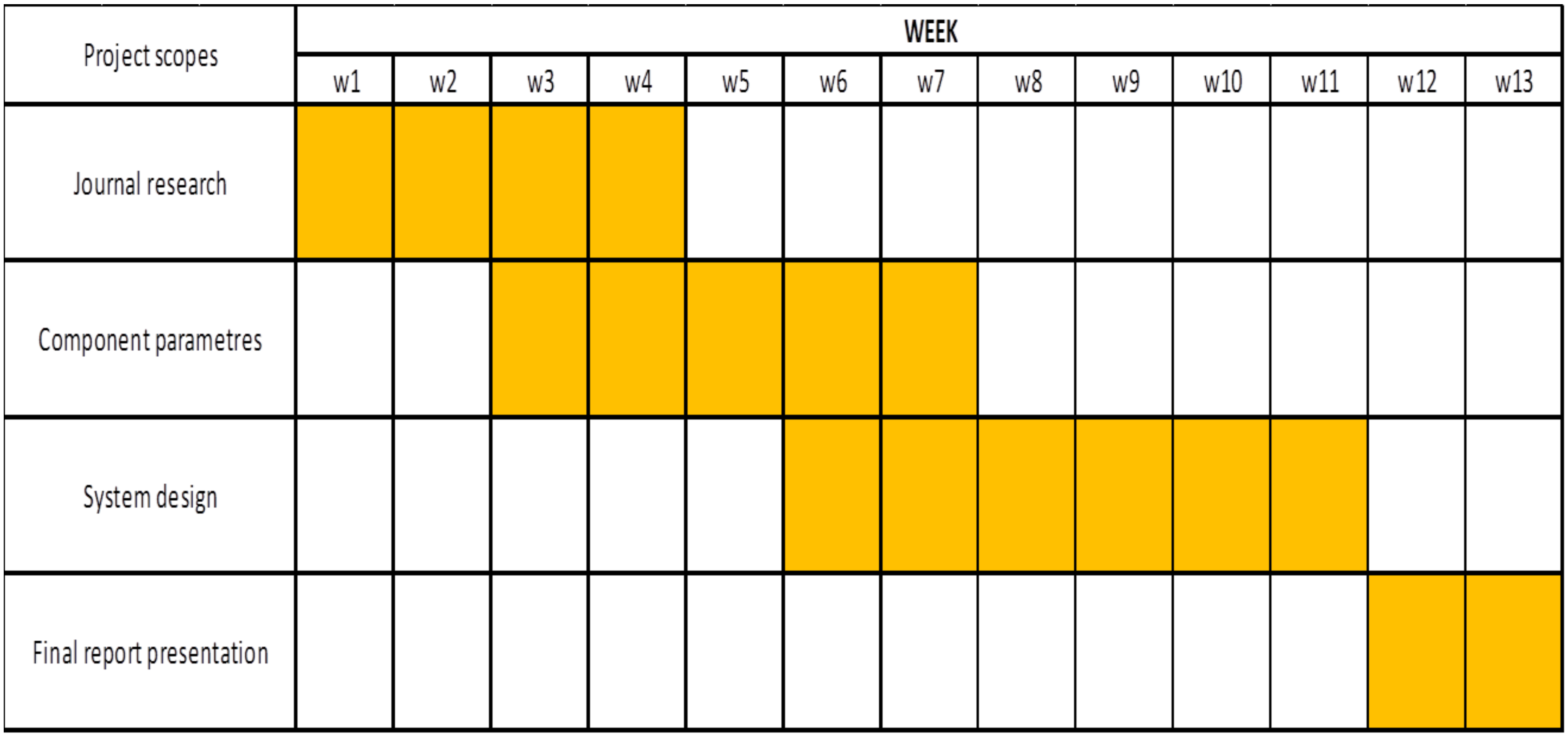

Figure 3.1: Gantt Chart

3.3 FLOW CHART